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AGROENGINEERING ASPECTS OF PROCESSING BULK HAY

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The article presents the results of research on the technological process of hay harvesting with additional drying of grass by active ventilation. In Ukraine, the most widespread is the preparation of loose hay, the volumes of which exceed 70%. Loose hay is harvested by drying mowed grass in the field or by further drying with active ventilation. Harvesting loose hay by drying grass in the field is accompanied by significant losses of nutrients, which exceed 40%. The use of active ventilation allows you to reduce nutrient losses, since in this case the grass is taken from the field at a humidity of 35…40% and further dried by blowing atmospheric or heated air through the grass. Haystacks are used for drying with active ventilation, as well as closed rooms in which ventilation units can be installed. When choosing drying equipment, it is advisable to use such criteria as the possibility of obtaining feed with maximum preservation of nutrients at the lowest possible specific energy consumption for the process. Such drying equipment should have a simple design and ease of maintenance. Grass drying occurs due to the difference in water vapor pressure in the air and on the surface of the grass. The vapor pressure in the air that is pumped into the straw rick should be lower. This situation occurs when the relative humidity of the air in the pores between the plants is less than the equilibrium humidity of the air. It is shown that hay harvesting using active ventilation should be considered as a flow process that includes: mowing grass, drying mowed grass in the field, picking up and transporting the dried mass, drying the dried grass by active ventilation. To ensure the continuity of the flow, it is necessary to equalize the output for changing all links of the flow process complex. The dependencies are given, which allow determining: air velocity in the grass layer during ventilation; required fan performance; hay yield per hectare; specific pressure losses in the meadow clover layer; power of the electric motor for driving the fan; volume and quantity of harvested hay.

Keywords: *active ventilation, dried grass, hay, drying, pressure loss, flow process.*
Eq. 11. Fig. 4. Ref. 17.

1. Problem formulation

Hay is a feed that has been used in animal feeding since ancient times. This is the oldest method of preserving herbs, which has not lost its importance even today due to its availability, simplicity, and relatively high quality of feed.

According to standard terminology [1], hay is roughage obtained as a result of dehydration of grass to a moisture content of no more than 17% by air-solar drying or air-solar drying to a moisture content of (35…40)% with subsequent drying by active ventilation, i.e. when harvesting hay, drying of mowed grass can be carried out in two ways: a) naturally under the influence of the sun and wind; b) drying in the field with further drying of the collected mass by forced blowing of atmospheric or heated air through it.

A necessary condition for the loss of moisture by mowed grass is the supply of heat to it. Therefore, field drying technologies for harvesting hay are less energy-intensive because they do not require additional energy costs for drying grass except for the energy of the sun and wind [2, 3]. However, drying grass in natural conditions

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depends on many random uncontrollable weather factors and not always, technologies based on this drying method can ensure the harvesting of high-quality hay.

In variable weather, the duration of natural drying increases. The longer the drying takes, the greater the likelihood that the cut grass will be exposed to precipitation (rain, hail, fog), which leads to leaching of the most digestible nutrients and a decrease in the intensity of drying.

Hay made from grass that has been exposed to prolonged rain during the drying process becomes moldy and has an unpleasant odor. Sometimes such hay turns brown and has low protein digestibility [4].

With long-term drying, plants are unable to resist the vital activity of mold fungi and other harmful microorganisms, which also leads to a decrease in the nutritional value of hay.

Significant losses of grass nutrients , primarily protein during field drying encourages improvement of hay harvesting technologies. Accumulated experience shows that nutrient losses can be reduced, and therefore hay quality can be improved, by artificially drying the grass dried in the field by active ventilation [5].

Drying mowed grass during haymaking is a complex technological process, which is accompanied not only by losses of moisture but also nutrients by plants. Therefore, the correct choice of drying methods and modes remains one of the main tasks of any haymaking technology.

2. Analysis of recent research and publications

Drying of mowed grass is a complex process, which is accompanied by losses of mowed plants not only of moisture, but also of nutrients as a result of biochemical processes, the vital activity of microorganisms, and leaching by precipitation. Moreover, the rates of all losses increase as the drying duration increases [6, 7].

The authors [8] developed a mathematical model of drying of leafy-stem material, which includes dried grass, by active ventilation. The developed model allows to determine the change in the moisture content of the material over time, taking into account the heat of self-heating and natural compaction of the material. In the studied processes of active ventilation [9] and drying of agricultural crops, the processes of ensuring their effective storage and increasing the energy efficiency of technological processes were considered.

Derkach V. V. [6] proposed a mathematical model for determining the duration of field drying of mowed alfalfa during hay harvesting, which takes into account the influence of natural climatic factors on the process.

In publications [3, 4, 5, 9, 10, 11, 14] it is shown that in order to reduce losses and obtain high-quality hay, it is advisable to use the active ventilation method, which involves collecting withered grass from the field with a humidity of 35…40 %, after which it is dried using cold or heated air distribution systems. The air supplied by the fan actively circulates in the middle of the haystack or stack of grass, gradually removing moisture.

Despite a significant number of scientific publications in the field of hay harvesting using active ventilation, there are many unresolved problems that hinder the widespread introduction of this method of hay harvesting into production.

3. The purpose of the article

Highlighting the agro-engineering aspects of the technology of bulk hay harvesting, aimed at maximum preservation of nutrients in green mass. Special attention is paid to the study of the processes of grass drying by active ventilation, as well as substantiation of air supply parameters and energy consumption of the drying process.

4. Results and discussion

In Ukraine, the most widespread method of hay harvesting is loose hay. The volume of such hay harvesting exceeds 70 % [10, 11]. Loose hay is harvested by drying the cut grass in the field or by further drying with active ventilation.

Harvesting loose hay with field drying of grass is accompanied by significant losses of nutrients. Thus, the authors [12] claim that the actual losses during harvesting of loose hay with field drying can exceed 40%.

The use of active ventilation for hay harvesting reduces nutrient losses, since in this case the grass is collected from the field at a humidity of 35…40 % and dried with atmospheric air or 40…45 % with the following drying with air heated, but not more than 5…7 °C. The use of this technology reduces the loss of the most valuable parts of plants in terms of feed – leaves and inflorescences.

When harvesting loose hay with active ventilation, the grass is mowed with or without flattening and dried in swaths. To speed up the drying process, the grass is periodically stirred. When the moisture content of legumes reaches 55...50 %, and that of cereals 50...45 %, they are raked into windrows, in which the grass is dried to a moisture content of 40...45 %. After that, the grass is removed from the field and dried in storage places on special air distributors by blowing atmospheric or heated air through the grass layer.

When drying herbs in the field, the following must be taken into account:

- when harvesting hay, one should try to preserve the maximum amount of leaves, since protein is mainly contained in the leaf mass of grasses, due to the reduction to a minimum of the drying process in mowing and windrows;
- mowed grass in swaths should be raked into windrows in dry weather;
- it is impractical to overdry grass in swaths, as this can lead to large losses due to the breaking off of leaves and inflorescences when raking into swaths;
- to reduce nutrient losses, it is necessary to dry grass not in rolls, but in swaths;
- if the grass is mowed with a windrow mower, it is necessary to spread the windrows;
- during the drying process, it is necessary to stir the grass with the obligatory turning of the grass layer;
- the duration of drying of cut grass in the field should not exceed two days.

It is necessary to comply with the above requirements for the reason that individual parts of the plant give off moisture unevenly. Leaves dry faster than stems, since their surface area, which evaporates water, is much larger than that of stems. In leaves, the path of moisture movement from the inner layers of cells to the outer ones is shorter. In addition, the stems of legumes are covered with a waxy layer, which makes it difficult for water to evaporate directly. As a result, the leaves of herbs, due to the peculiarities of their anatomical structure, acquire moisture much faster than the stems, at which they become brittle and are crushed under the action of the working parts of machines and are irretrievably lost [13].

For drying by active ventilation and subsequent storage of hay, haylofts built according to standard designs are used, as well as closed barns, sheds, attics of livestock farms and other premises in which ventilation units can be installed. If the above types of storage are not available, then the dried grass is dried in sheds formed on specially equipped open areas.

When choosing a place and equipment for drying dried grass, it is advisable to use such criteria as the possibility of obtaining feed with maximum preservation of nutrients at the lowest possible specific energy consumption for the process. Such drying equipment should have a simple design and ease of maintenance.

In rooms and sheds, the grass can be dried in layers or, provided that a stack or shed is formed, in one go - in one day.

During layer-by-layer drying in haylofts, the dried mass is laid evenly over the entire area of the air distribution system so that it extends 1.0…1.5 m beyond the lattice flooring. Ventilation begins after the grass mass has been laid over the entire area of the installation in a layer of at least 1.5 m. Then, with the fan turned on, this layer is increased to 2.0…2.5 m. After the grass has dried on the surface of the laid layer to a humidity of 25%, a second layer 1.5…2.0 m high is laid and drying is continued. Layer-by-layer laying of the grass mass is continued until the storage is filled.

If the initial humidity of the grass is 25…30 %, it is placed for drying in one go.

The stack for drying grass by active ventilation can also be formed in one or more stages, usually two. When forming the stack in two stages, first a layer of grass with a height of 2.0...2.5 m is placed on the air distribution system of the drying installation. In the second approach, the height of the stack is increased to 5.5...6.0 m, that is, to the height of the stack. The second layer is placed when the humidity of the first drops to 25%.

For drying herbs in large-volume sheds, air ducts up to 20 m long are used. In this case, fans are installed on the ends, and in the middle, the air duct is separated by a blank partition.

When drying dried grass in barns or haylofts, it should be placed as loosely as possible on the air distribution systems of the drying plants. Mass that has high humidity from rain or dew should not be placed for drying.

Haystacks for drying grass are formed on elevated places that are not flooded by rainwater. The ground at the site where the haystack is laid is tamped. The middle of the haystack base should always be higher than the edges. The top of the haystack must be fixed with poles or a wire with a load so that the wind does not blow away the freshly laid grass. Before starting to form the haystack, it is necessary to lay a layer of straw 0.2...0.3 m thick around the air distributor to reduce damage to the hay during long-term storage. The haystack or stack must be formed from grass that has approximately the same humidity.

When drying grass in an open area, it is necessary to have a tarpaulin or polyethylene film to cover the shed in rainy weather.

Each of the methods of laying grass for drying has its advantages and disadvantages. Layered drying extends the process to 14…16 days for loose hay and 18…30 days for pressed hay. For grass laid for drying in two stages per square meter of ventilated area, it is necessary to supply 300…450 m^3 of air per hour, and when drying grass laid in one stage, the air supply is doubled. This increases energy consumption, since the aerodynamic resistance to blowing grass increases [14].

Plants for drying dried grass mass by ventilation consist of a fan and an air distribution system. The simplest plants in terms of design have only a central air duct of trapezoidal, square or triangular cross-section. Previously, the industry produced UVS-10M and UVS-16 drying plants. They were intended for drying crushed and uncrushed dried grass by ventilation in sheds and rooms with cold or heated air.

When using the UVS-10M installation, a straw rick is formed with a length of 12…13 m, a width of 5.5…6.5 m and a height of 6…7 m, and when using UVS-16A, respectively, 18…19 m; 5.5…7.0 m and 7 m.

The air duct can be made directly on the farm from poles, rails, metal. In cross section they are a triangle or a trapezoid, they can be made solid or prefabricated (from several sections). For straw rick, the air duct is mostly made trapezoidal in shape: height 2 m, width near the ground - 1.5 m, at the top - 1.0 m. The length of the channel depends on the size of the straw rick, but should not exceed 18 m according to hydraulic requirements. The channel is usually 1.5...2.0 m shorter than the straw rick. The area of the holes in the walls of the channel should be at least 50% of its total surface. Channels are made with both a constant cross section and a variable one. In the latter case, the cross section of the end of the channel opposite the inlet opening should be approximately 1/3 of the area of the inlet cross section. On the fan side, the channel is closed for approximately 1.5...2.0 m along the entire perimeter, its rear end wall is also solid. The cross-sectional area of the channel on the fan side should be selected to ensure an air velocity in it of no more than 4...5 m/s.

Depending on the area of the air distribution system and the air flow rate, the air flow velocity in the duct can be determined by the formula:

$$V = \frac{Q}{3600S}, \tag{1}$$

where V is the air flow velocity in the duct, m/s; Q is the fan performance, m^3/h; S is the area of the air distribution system of the ventilation installation, m^2 .

The disadvantage of air ducts of this design is the small ratio of their surface to the volume of grass in the chute, resulting in significant pressure losses created by the fan.

More advanced air distributors, which ensure uniform air distribution over the entire storage area (straw rick) with a lower pressure drop, consist of a main channel and side grid floors. Such air distributors are used both for drying hay in open areas and in haylofts, barns and under sheds.

Drying grass by active ventilation is based on the use of the voids of porosity the grass mass, i.e. the presence of numerous voids between the plants, interconnected by air channels of various cross-sections and lengths (Fig. 1). The voids between the plants form an air duct system in the grass stack, through which air can move in any direction. The air flow affects the temperature and humidity of the grass, changes the gas composition of the air in the voids between the plants, i.e. affects precisely those factors on which the drying speed and preservation of the nutrients of the grass depend. The voids of the grass stack affect the resistance to the air flow, the uniformity of the grass moisture, the height of the stack and the type of fan.

The drying process occurs as a result of the movement of moisture from the middle of the vegetative organs of plants (stems, lateral shoots, leaves) to their outer layers. When air flows around the wet parts of plants, water evaporates and leaves the surface of the material, passing into the environment . Evaporation of moisture from the surface creates a difference in moisture content in the middle of the vegetative organs and the surface layers. Thus, during the drying process, moisture is continuously supplied from the inner layers to the surface, as a result of which its level decreases not only on the surface, but also in the depth of the material.

The drying of grass occurs due to the difference in water vapor pressure in the air and on the surface of the grass [9]. The vapor pressure in the air that is pumped into the straw rick should be lower. This situation occurs when the relative humidity of the air in the pores between the plants is lower than the equilibrium humidity of the air. Evaporation of water from the surface of the grass is accompanied by an equalization of its moisture content inside, so the moisture is removed to the outside. The speed of equalization of moisture inside the grass depends on its size: the greater the thickness of the vegetative organ of the grass, the slower the equalization.

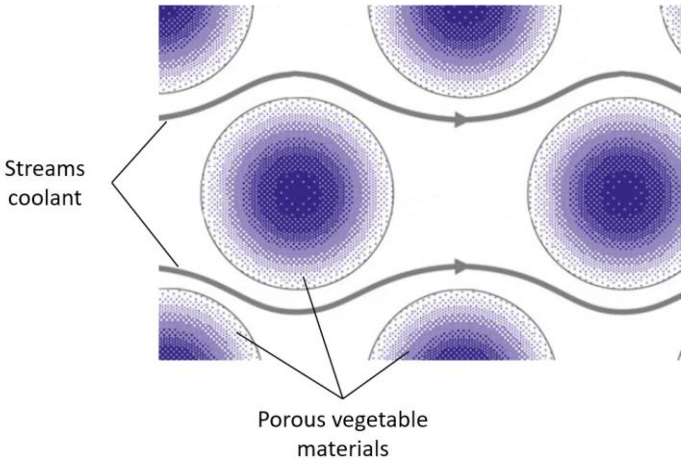

Fig. 1. Scheme of air movement through a layer of withered grass during active ventilation

The duration of drying by active ventilation of grass depends on its humidity and ventilation modes. To avoid mold in the grass, the drying time should not exceed 15 days, and to reduce nutrient losses, it is not necessary to allow the grass to self-heat above 40 °C.

The first two days of drying the pile of grass is ventilated continuously regardless of the weather. In the future, the fans are turned on when the relative humidity of the air is less than 75% and the temperature is more than 15 °C. During the rainy period of drying, the fans are not turned on. During prolonged bad weather, when the temperature of the mass rises above 40 °C, it is cooled, periodically turning on the fan [5].

During the day, the relative humidity of the air changes. Therefore, to determine the duration of drying, it is necessary to know the duration of the period favorable for drying, at which the relative humidity of the air is less than the above-mentioned level. For example, according to [4], the possible duration of ventilation during the day in the Vinnytsia region is 15 hours.

A significant influence on the intensity of drying of dried grass by active ventilation is its self-heating, which occurs as a result of biological processes and the vital activity of microorganisms in the grass. The self-heating of grass is affected by its humidity and temperature. The intensity of self-heating decreases with a decrease in grass humidity, and when the conditioned humidity of hay is reached, heat release stops. Heat release is accompanied by the breakdown of carbohydrates and loss of nutrients. As a result of self-heating of dried grass during its drying by active ventilation, 5-10% of dry matter is lost [15].

An increase in the temperature of grass from self-heating above 40 °C is especially dangerous, because in this case irreversible processes occur associated with the denaturation of proteins, which leads to a decrease in their digestibility by animals.

Nagriv air reduces drying time. It is known that an increase in air temperature by 1°C reduces its relative humidity by 5%, increasing its ability to absorb moisture by approximately 0.25 g/m^3 .

It should be noted that drying grass by ventilation, even atmospheric air, is a relatively energy-intensive process, because to obtain one ton of hay from grass with a moisture content of 35…40 %, it is necessary to spend almost 120 kW/h of electricity [16].

It is clear that reducing the duration of ventilation by heating the air with electric heaters or heat generators will lead to additional consumption of energy resources when harvesting hay.

For energy saving reasons, preheating of air has not become widespread in Germany and is decreasing in the USA. Due to climate change in Ukraine, hay harvesting using unheated air is the most effective.

Drying of dried grass by active ventilation should be organized so that there is no accumulation of it near haystacks or in places where drying is organized, which will allow to avoid its self-heating. This means that the equipment for harvesting hay: mowers, tedders , rakes, and drying units should have coordinated performance.

Harvesting loose hay using active ventilation can be considered as a flow process (Fig. 2), which includes the following technological groups: mowing grass, drying mowed grass in the field, picking up and transporting the dried mass, drying the dried grass by active ventilation.

To ensure the continuity of the flow, it is necessary to have equal output for changing all links of the flow process complex:

$$W_{p.p.}U = W_1 n_1 T_1 U = W_2 n_2 T_2 U = ... = W_n n_n T_n U, \quad (2)$$

where $W_{p.p.}$ is the output per change of the flow process, t/shift; W_1, W_2,…, W_n are the hourly technical productivity of units in separate technological groups of the flow process, t/h; n_1, n_2, …, n_n are the number of units or transport units in the corresponding technological groups; T_1, T_2,…, T_n are the duration of operation of each technological group, h; U is the hay yield, t/ha.

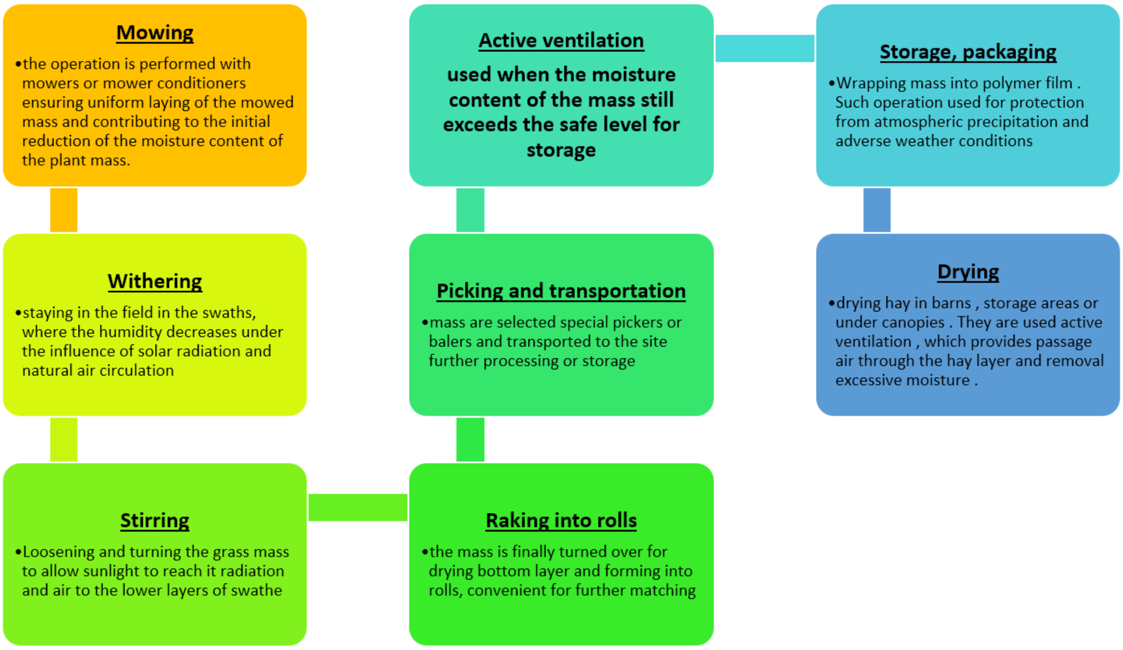

Fig. 2. Technological scheme of hay harvesting with additional drying by active ventilation

The yield or harvest of hay per hectare can be determined if we assume that during the haymaking process the dry matter of the grass is not lost, but only the evaporation of moisture occurs. Then, based on the material balance of the conservation of dry matter, we will have:

$$U = \left(\frac{100 - a_t}{100 - a_c}\right) U_t, \quad (3)$$

where a_t і a_c respectively, are the moisture content of grass and the onditioned moisture content of hay, %; U_t is the grass yield, t/ha.

Sometimes when drying grass by active ventilation, it is necessary to know how much water needs to be removed from the dried grass to obtain hay. It can be determined by the formula:

$$G = \left(\frac{a_{p\,t} - a_c}{100 - a_c}\right) U_{p\,t}, \quad (4)$$

where G is the mass of water that needs to be removed, t; $U_{p\,t}$ is the mass of dried grass, t; $a_{p\,t}$ is the humidity of dried grass, %.

Equation (4) is used to construct a surface dependence (Fig. 3) of the mass of water that must be removed from the dried grass during drying by active ventilation. Surface analysis shows that with increasing humidity and mass of the grass mass, the amount of water that must be removed increases significantly.

During the drying process, the air flow, which is blown by the fan when it meets the grass layer, is divided into a large number of smaller flows that move in the winding voids between the vegetative organs of plants and wash almost every plant. Passing through the dried grass, the air has a different effect on it. Under its action, the gas composition of the air in the pores between the vegetative organs of plants, the temperature and humidity of the grass and the intensity of microbiological processes in the plant mass change.

During ventilation, the air flow due to the static pressure created by the fan must overcome the aerodynamic resistance of the grass layer. Since the total pressure developed by the fan is equal to the sum of the static and dynamic pressure, in order to increase the static pressure, it is necessary to reduce the dynamic pressure. This can be achieved by reducing the speed of air movement in the grass layer. The passage of air through the layer leads to pressure losses. The term "pressure loss" means the difference in pressure between two cross-sections perpendicular to the direction of air supply, laid out for drying grass, through which cold or heated air passes.

Pressure losses during ventilation are mainly associated with the passage of air through a dense layer of grass, where they depend on the stacking density, moisture and particle size of the hay, as well as on the air flow velocity, creating hydraulic resistance that reduces ventilation efficiency and increases energy consumption.

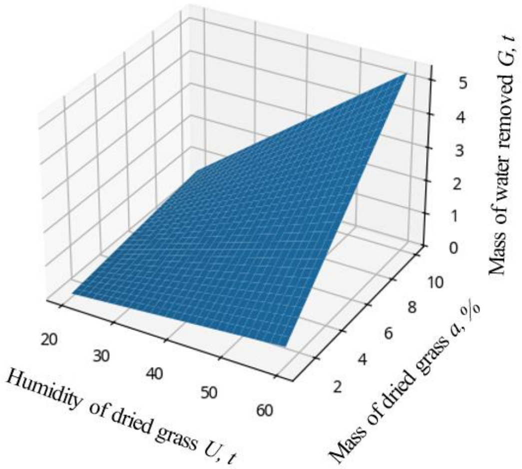

Fig. 3. Dependence of the mass of water removed during active ventilation on the humidity and mass of dried grass

It has been established that a layer of dried meadow clover resists the movement of air when it is supplied against the direction of natural compaction, which can be determined by the dependence:

$$\Delta P = 0{,}083\rho^{2.6}V^{1.7}, \tag{5}$$

where ΔP is the specific pressure loss, Pa/m; ρ is the volumetric mass of grass, kg/m^3; V is the air velocity in the grass layer, m/s.

The duration of drying, and therefore the energy consumption, depends on the moisture content of the grass and the ventilation modes. For example, when drying one ton of dried grass with a moisture content of 35% to 17%, 217 kg of water must be removed by active ventilation.

In active ventilation installations for drying grass, centrifugal (radial) fans of general industrial purpose of low pressure are used. Compared to axial fans, they are characterized by increased fire safety, stable operation with increased aerodynamic resistance of the layer of plant mass and the ability to provide the necessary air pressure for the effective passage of the air flow through the layer of hay. It is possible to choose a fan for active ventilation based on its aerodynamic characteristics, which are given in the fan's operating instructions, when its performance and the pressure it must create are known.

The required fan performance can be determined using the following formula:

$$Q = S\mu\,, \tag{6}$$

where Q is the air flow rate, m^3/h; μ is the specific air supply for ventilation, m^3/(m^{2}h); S is the ventilation area, m^2.

Based on the calculations of the fan performance, a surface dependence (Fig. 4) of the specific heat consumption for drying grass on the temperature of the drying agent was constructed. t_1 and the increase in air moisture content (x_2 - x_1). Analysis of the graph shows that with increasing air temperature and increasing moisture content of the drying agent , the specific heat consumption of the drying process changes, which allows us to assess the energy efficiency of the drying unit.

When drying grass in layers, 300…450 m^3 of air is supplied per square meter of ventilated area per hour, and when drying grass laid in one approach μ = 700…900 m^3/(m^{2}h) [14]. From the known values of air flow rate Q, specific pressure losses for blowing the grass layer ΔP and the layer thickness H, it is possible to determine the power N (kW) of the electric motor for driving the fan:

$$N = \frac{Q\, \Delta P_{g.l.} H}{1000\, \eta\, 3600}, \quad (7)$$

where N is the electric motor power, kW; $\Delta P_{g.l.}$ is the pressure loss in the grass layer, Pa; H is the thickness of the grass layer, m; η is the efficiency coefficient of the fan, η = 0.5…0.8.

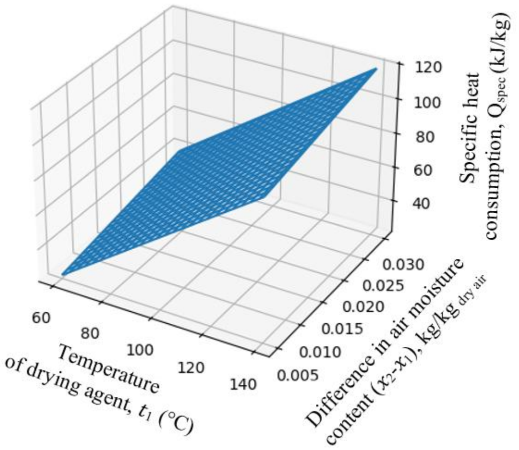

Fig. 4. Surface dependence of specific heat consumption for drying grass on the temperature of the drying agent and the increase in air moisture content

Based on the specified parameters, a fan is selected that provides the required air flow, pressure, and power.

When choosing a fan, special attention should be paid to the compliance of its performance and developed pressure with the required flow and pressure indicators obtained during aerodynamic calculations during the design of active ventilation systems for drying grass.

To determine the readiness of hay for long-term storage, it is necessary to walk along the haystack after turning off the fans and then turning them on again after 8-10 hours and determine with a pyrometer whether warm air is coming out of it. If warm air is detected, ventilation is continued until the hay moisture reaches 17…18%.

After the haymaking work is completed, it is necessary to determine the amount of harvested hay. To do this, measure the size of the haystacks and determine their volume. Knowing the volumetric weight of the hay, determine the amount of harvested hay:

$$M_c = \sum_{i=1}^{n} V_{ci}\, \rho_{ci}, \quad (8)$$

where M_s is the total mass of harvested hay, t; V_{ci} is volume of the i-th type of hay, m^3; ρ_{ci} is volumetric mass of the i-th type of hay, t/m^3.

The volume of the straw rick is determined by the formulas [17]:

− round-topped straw rick of low and medium height

$$Vc = (0.52l - 0.45b)\, bz\,; \quad (9)$$

where Vc is the volume of the straw rick, m^3; l is the distance from the ground on one side of the straw rick through the top to the ground on the other side of the straw rick, m; b and z are the width and length of the straw rick respectively, m.

− high straw rick with a round top

$$Vc = (0.52l - 0.46b)\, bz\,; \quad (10)$$

− flat-topped straw rick

$$Vc = (0.52\, l - 0.55b)\, bz\,; \quad (11)$$

The length and width are measured at chest height on both sides of the straw rick and the average data is used for calculations.

The weight of one cubic meter of hay can be determined by control weighing of the feed in one of the typical haystacks 1.5 months after laying. When it is not possible to conduct a test weighing, reference data can be used.

5. Conclusion

Taking into account the above, it can be stated that the set of technological techniques used in haymaking using active ventilation for winter animal housing should ensure the maximum possible preservation of useful nutrients in grass and a combination of rational schemes for heat supply and removal. To achieve this goal, it is necessary to improve the equipment used for haymaking, which should be determined by the complex of characteristics of the material as an object of drying, the range of equipment produced, and the features of production, allowing to reduce nutrient losses during mowing, stirring, transportation to the drying site, drying and storage.

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АГРОІНЖЕНЕРНІ АСПЕКТИ ЗАГОТІВЛІ РОЗСИПНОГО СІНА

У статті представлено результати дослідження технологічного процесу заготівлі сіна з додатковим підсушуванням трави активним вентилюванням. В Україні найбільшого поширення набуло приготування розсипного сіна, об'єми заготівлі якого перевищують 70 %. Розсипне сіно заготовляють з сушінням скошеної трави в полі або з досушуванням активним вентилюванням. Заготівля розсипного сіна з сушінням трави в полі супроводжується значними втратами поживних речовин, які перевищують 40 %. Використання активного вентилювання дозволяє зменшити втрати поживних речовин, оскільки в цьому випадку траву забирають з поля при вологості 35…40 % і досушують шляхом продування крізь траву атмосферного або підігрітого повітря. Для сушіння активним вентилюванням використовують сіносховища, а також закриті приміщення, в яких можуть бути змонтовані вентиляційні установки. При виборі устаткування для сушіння доцільно користуватися такими критеріями, як можливість отримання корму з максимальним збереженням в ньому поживних речовин при можливо меншій питомій витраті енергії на процес. Таке сушарне устаткування повинне мати просту конструкцію і зручність обслуговування. Сушіння трави відбувається за рахунок різниці тиску водяної пари в повітрі і на поверхні трави. Тиск пари в повітрі, яке нагнітається в скирту має бути нижчим. Така ситуація виникає, коли відносна вологість повітря, що знаходиться в порах між рослинами, менша рівноважної вологості повітря. Показано, що заготівлю сіна з використанням активного вентилювання доцільно розглядати як потоковий процес, який включає: скошування трави, сушіння скошеної трави в полі, підбирання і транспортування прив'яленої маси, сушіння прив'яленої трави активним вентилюванням. Для забезпечення безперервності потоку необхідна рівність виробітку за зміну всіх ланок комплексу потокового процесу. Наведені залежності, які дозволяють визначити: швидкість повітря в шарі трави при вентилюванні; необхідну продуктивність вентилятора; вихід сіна з гектара; питомі втрати тиску в шарі конюшини лучної; потужність електродвигуна для приводу вентилятора; об'єм і кількість заготовленого сіна.

Ключові слова: *активне вентилювання, прив'ялена трава, сіно, сушіння, втрати тиску, потоковий процес.*
Ф. 11. Рис. 4. Літ. 17.

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